

Models and Simulations

It's all about the assumptions!

*A brief excursion through some modeling
methods and their use*

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Why Chose a Particular Model or Sim

- **Access and Experience**
 - Access: it's available now as is the data
 - Experience: you've used it before, have people who can run it, and understand how the data integrates
 - As a subject matter expert, you know its warts and are comfortable with it
- **Suitability**
 - *And sometimes you just can't get what you need – you know it's not what you need but it's the only thing you've got*
- **In the End**
 - It's the assumptions that count
 - Modeling methodologies are limited by their assumptions
 - Exercising them outside their domain of suitability is possible -- *caveat emptor*
- ***Critical differences among modeling methodologies are rooted in their assumptions***
- ***For all models, particularly those dealing with humans, acquiring the right data is an issue***

- **Bayesian inference computations**
 - Rigorous mathematical roots in statistics
 - Based on the ability to compute (or assign) likelihood functions
 - Uniqueness of Bayes: inclusion of prior information in computation of current state
 - Statistical, not evolutionary or chaotic
- **Two primary applications of Bayesian inference**
 - Inferential Exploration (data mining): discovering hidden links, relationships, similarities in a large set of data (NP-hard problem as number of links grow: 5 links, 2^5-1 variables)
 - Inferential Projection: using existing relationships (priors) estimate the probability of the next state based on new information
- **Rich Application Domain for Bayesian inference**
 - Multiple target tracking (submarine warfare)
 - Microsoft Office Assistant: Bayesian inference used to anticipate the user's proximate needs
 - Human influence networks and systems involving humans

Daryle Niedermayer, "An Introduction to Bayesian Networks and their Contemporary Applications", http://research.microsoft.com/adapt/MSBNx/msbnx/Basics_of_Bayesian_Inference.htm

Using a Bayesian Inference Model

- **Preparation: Determining the Priors**
 - Relationships (statistical priors) are normally done by extracting knowledge from subject matter experts
 - Good estimates are critical because you are building the complete mathematical structure on the basis of this knowledge
 - Just think about how your results are affected if you miss the fact that the person you are interested in has always consulted his mother's first cousin before acting - --- and you didn't know he existed!
 - The network matters – the whole network
- **What's static: the network of beliefs or influential individuals established in the prep stage**
 - This is hard to modify – it's the backbone for your model
- **What changes: the probabilities or levels of belief based on the newly introduced evidence**
 - You can actually use these as parameters and vary them to test sensitivity

- **SIAM**
 - Human influence network
 - For a long time the best available model
 - Acquisition of data, very expensive, human intensive
- **Pythia**
 - Continuing academic development by team that built Siam
 - Not focused solely on people – does events as well
 - Adds time component (not just the likelihood of influencing, but over what potential time frame)
 - Adds optimization tools to create “effects based” event timing
- **JCAT**
 - Like Pythia, extended application beyond influence nets
 - Unlike Pythia, was made operational by USAF and is currently in use in Iraq, for example, to make sense out of observations
 - Available to government users

System Dynamics Models

- **Developed by Dr. Jay W. Forrester, MIT in the mid-1950's**
 - Based on the stock-flow-feedback structure of GE plants, but included the influence of corporate decision making structure for hiring and layoffs.
 - Focused on behavior of a system over time
 - Principle: all dynamic behavior in the world occurs when flows accumulate in stocks
 - ISSUE: identification of all the stocks, flows and feedbacks in the system to be modeled
 - PROBLEM: identifying all the correct relationships that link the stocks, flows and feedbacks
- **Multiple Application Domains**
 - Applied to corporate management
 - Extended to Urban Dynamics with counter-intuitive, but provable results
 - Extended to World Dynamics, a socioeconomic model that incorporated the natural resources and human consumption
 - Extensively used across all energy domains
 - Recently extended to the insurgencies and recruitment

DOE Systems Dynamics Tutorial: [http: www.systemdynamics.org/DL-IntroSysDyn](http://www.systemdynamics.org/DL-IntroSysDyn)

Using System Dynamics Models

- **Preparation: Determining the Priors**
 - The identification of stocks, flows and feedbacks are done by those who know the system in question
 - Serious, non-linear mathematical relationships underlie the framework, BUT in human system, particularly where the organization is not well known, these are hard to determine
 - Bounding the system is a practical problem, especially when not all the flows or stocks are identifiable
- **What's static: the network of stock, flows and feedbacks**
 - This is hard to modify – it's the backbone for your model
- **What changes: rates of flow and triggers for feedbacks**
 - You can actually use these as parameters and vary them to test sensitivity

- **Computational Construct**
 - Descended from Cellular Automata
 - Not based on differential equations, statistical models
 - Local interactions give rise to global behaviors not directly associated with the local rules (local infers some proximity – not necessarily geographic or grid)
- **Why are ABMs interesting to social scientists**
 - Formalisms appear more natural for problems of social science
 - Agents as a natural ontology for many social problems
 - Agents modeled as individuals or organizations allow for descriptive heuristics that incorporate large quantities of data and knowledge, particularly relationships
 - Emergence
 - Micro-motives lead to Macro-behaviors
 - Social norms and structures can “emerge” from the interactions of the individual agents
- **What’s static: the heuristics that constitute the micro-motives**
 - Unfortunately, unique in nearly every case
- **What changes: not restricted by the computational framework**

Using Agent Based Models

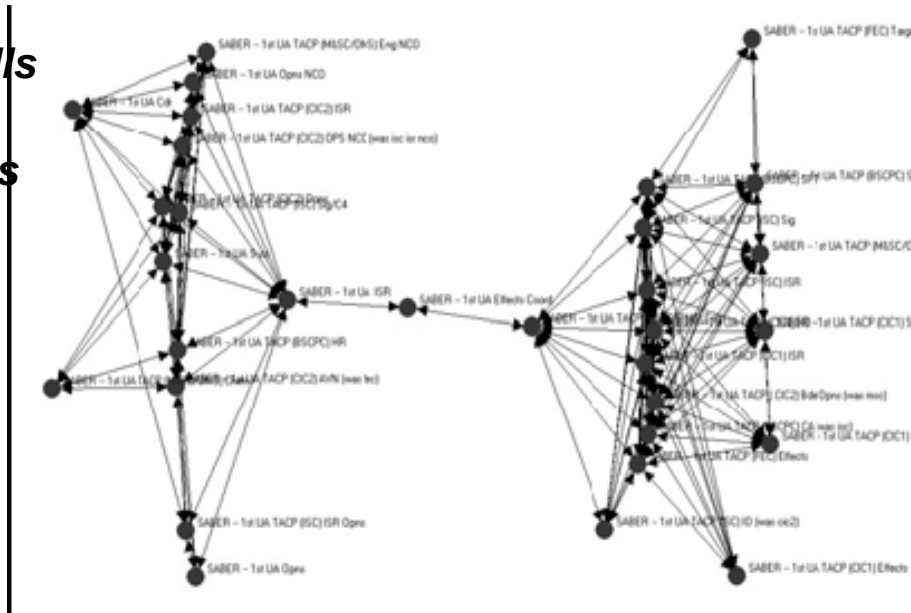
- **The way the heuristics are developed, distinguishes different ABMs**
- **McKerrow (LANL) modeled Pashtun tribes**
 - Agents are demographically characterized
 - Each demographic type has roles, goals, rules and relationships
- **Silverman (UPenn)**
 - Heuristics based on a tree structure of actions and interests drawn from psychological literature
 - Injects affective behaviors to modify decisions
 - Has modeled individual decision makers and gives them budgets of capabilities including military force and influences

Agent-based models are a computational concept – different heuristics => different models

Mathematical: graph theory and computes using graph theoretical methods
Structures: derived directly from sociology, anthropology, organizational structure

- ***People***
- ***Units of action***
- ***Coalition partners***
- ***Departments***
- ***Resources***
- ***Ideas or Skills***
- ***Events***
- ***Nation-states***

- **Who do you like or respect?**
- **Transfer of resources**
- **Authority lines**
- **Association or affiliation**
- **Alliance**
- **Substitution**
- **Precedence**



- **Relations constrain and enable behavior**
 - Network structure impacts performance, information diffusion, technology adoption, disease spread ...
 - Individual's position in network influences chance of promotion, ability gather and relay information, ability to influence and be influenced
 - “Health” of the organization can be assessed by examining networks
 - When information is uncertain people rely on their networks make decisions
 - Organization's position in inter-organizational network controls access to resources and information
 - Manager's perception of inter-organizational network influences alliance decisions such as mergers and joint ventures
- **What's static: the network structure**
- **What changes: relative strength of ties**
- **Dynamic Network Analysis:**
 - Combines social networks and ABMs
 - Designed to allow networks to become complex, adaptive structures

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- **Not so much a model as a framework**
- **Based on typologies for decision makers, state and non-state**
 - Objectives, motivations, capabilities, functional environments and decision-making modes
- **Extracts from the typologies are used to build a decision calculus**
 - What does the adversary want to do
 - What interest does it serve
 - What are the risks and benefits associated with doing it or refraining from doing it
 - What does the adversary think we would do and how does that modify his risk/benefit assessment
 - Add to that what we think we would do and attempt to determine the adversary's reaction
- **New Concept and framework – shows promise and can be used with computational models**